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Interdependencies Among the Irish, British and German Stock Markets

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Abstract: Interdependencies between the Irish stock market and two other stock markets, namely the United Kingdom and Germany, are assessed. The indices used are the ISEQ, the FTSE-100, and the FAZ. The application of cointegration techniques suggest that a long-run relationship does not exist between either the stock markets' price levels or their rates of return. There is however, a significant increase in the correlation between short-run returns across the markets after the 1987 stock market crash. Greater stock market integration has coincided with greater financial and economic integration. No lead-lag relationships are found for the pre-crash period in applying Granger causality tests. However, important uni-directional causality is found for the post-crash period. Indicating that the Irish stock market is inefficient. Significant contemporaneous causality is detected for the period of the stock market crash.

I INTRODUCTION

It is of particular interest to examine the interdependencies between the Irish, United Kingdom and German stock markets for the simple reason that these countries have high economic interdependencies with Ireland. Traditionally, Ireland's economy was linked with that of the United Kingdom. However, there have been considerable changes in the economic position of Ireland in relation to the UK and German economies since joining the ERM.[1] Recently arising from the September 1992 exchange rate crises there has

1. Giavazzi and Giovannini (1988, 1989), Callan and Fitz Gerald (1989), Kremers (1990), and Leddin (1991).

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been considerable debate about the influence of the UK and German financial markets on the Irish markets. Evidence of linkages between the countries is based on exchange, interest and inflation rates movements (Walsh 1993a, 1993b; and O'Leary, 1993). Stock market linkages has not been explored. There has been a convergence of inflation, interest and exchange rates to German rates; less so for the UK which remained outside the ERM until 1989 and left again in September 1992.

It is argued that the membership of the ERM, and thus the termination of the no margins exchange link with sterling, and the reduced reliance on UK markets has further resulted in the economic and financial integration of Ireland to Germany, as compared to the United Kingdom. In examining interest and inflation rates Walsh (1993b) provides econometric evidence to show that although up to 1992 Irish financial markets were increasingly influenced by German markets, the UK markets had remained as a highly significant influence on Irish financial markets.

The extent to which the Irish financial markets are integrated with the UK and German markets, leads to the expectation that interdependencies of the Irish stock market with both the UK and German markets should be observable. As Walsh (1993b) points out it is the degree of interdependency that is important. This is the issue addressed here.

In the next section the literature on the integration of stock markets is reviewed. In section III the data is described. Section IV outlines the theory and discusses the appropriate statistical methods of testing for short- and long-run stock market integration. Granger methodology is employed to test for uni-directional and bi-directional causality. Section V contains the empirical results. Section VI concludes the study, with implications of the cointegration and causality results for the Irish Stock Exchange and for market efficiency.

II INTEGRATION OF STOCK MARKETS

Integration of financial markets reflected in the interdependencies among national stock market indices has been the focus of numerous studies on the efficiency of international capital markets, especially equity markets. Market integration implies that assets of similar risk in different countries provide the same expected returns in some common currency. This issue has been addressed through a variety of tests and procedures. For example, Stehle (1977), Errunza and Losq (1985), Jorion and Schwartz (1986), and Hietala (1989) have all examined whether stock markets are segmented or integrated. Equities in a segmented stock market are priced according to factors particular to that domestic market. In an integrated market equities are

priced according to international factors.

Following Solnik (1974, 1977), assets are priced internationally by the following two equation model[2]

$$R_h^j = r_f + \beta_h^j (R^j - r_f) + \text{error} \tag{1}$$

for all h, and

$$R^j = r_f + \gamma^j (R^m - r_f) + u^j \tag{2}$$

for all j.

Where R^j is the required return on the market portfolio of country j, R^m is the required return on the international market portfolio, R_h^j is the required return on asset h in country j. The systematic risks of asset and country are given by β_h^j and γ^j, respectively. The degree of segmentation between the national and international stock markets is represented by the error term u^j, a measure of country-specific influences on stock prices.

If, as in the case of a number of studies,[3] a test is conducted for stock market integration using a universal asset pricing model, such as outlined above, the inevitable joint hypothesis problem arises, that is, are the assumptions of the model or market integration being tested? For this reason results have not been conclusive. Furthermore, even in the absence of market integration, internationally diversified portfolios could be mean-variance efficient. Thus, tests like those described above can be without power as tests of international stock market integration (Wheatley, 1988). However, this does not diminish the importance of the stock market integration question. For example, if the international market portfolio is mean-variance efficient, but asset markets are segmented internationally, then the cost of capital for a project will still generally depend on the country in which the capital is to be raised. This is because when asset markets are segmented internationally no individual will hold the world market portfolio.

Other international studies have examined the interdependencies and lead-lag relationships among national common stock indices (Agmon, 1972; Schollhammer and Sand, 1987; Khoury, Dodin and Takada, 1987). The results from these studies are mixed, and consequently consistent inference cannot be drawn.

A similar methodology is used by Donnelly (1991) for the Irish and UK stock markets. Using daily returns for the Irish Times-Cara Index and the

2. If a common currency is assumed, a common world risk-free rate of interest r_f can be used.

3. For example, Errunza and Losq (1985), Jorion and Schwartz (1986), Wheatley (1988), and Hietala (1989).

FT-All Share Index for the period January 1, 1975, to July 22, 1988, Donnelly found tentative support for the hypothesis that the London stock market influences the Dublin stock market with a lag. Donnelly was primarily concerned with seasonality factors in the Irish stock market. He, therefore, only provided a brief account of the lead-lag relationship.

More recent international studies have examined the degree of interdependencies using the concept of Granger causality (for example, Eun and Shim, 1989; Taylor and Tonks, 1989; Mathur and Subrahmanyam, 1990; Malliaris and Urrutia, 1992). This approach is not subject to *a priori* restrictions on the structural relationships among the variables. Thus the joint hypothesis problem, as mentioned above, does not arise.

III DATA DESCRIPTION

All data are weekly from Datastream (closing reading), unadjusted for the period January 17, 1983, to February 15, 1993.[4] The precise indices used are: (i) for Ireland, the ISEQ Index; (ii) for the UK, the FTSE-100 Index; and (iii) for Germany, the Frankfurter Allgemeine (FAZ) General Index. All data were deflated by the Irish pound exchange rate and converted to natural logarithms.

To investigate market integration using cointegration and Granger causality tests, returns are calculated and the data are divided into three sets. The weekly returns are calculated by the first differences of the natural logarithm of each price index j, converted into common currency, Irish pounds, terms. That is,

$$R_t^j = \mathrm{Ln}\left(P_t^j\right) - \mathrm{Ln}\left(P_{t-1}^j\right) \tag{3}$$

for any stock market j and where P^j denotes the price level of index j in Irish pounds.

The sample is divided into three time periods to capture the effect of the 1987 stock market crash as well as the greater economic and financial integration of Ireland with Germany. The timing of subperiods is influenced by trends in key economic variables, political events and a number of recent studies on Ireland's experience in the ERM. Most recently, Walsh (1993a, pp. 1-2, 4) argues that "between the first quarter of 1979 and the first quarter of 1986 ... there was little evidence of convergence of Irish interest rates or

4. The source of the data is Datastream but it has also been cross-checked with the *Financial Times*. The price indices and exchange rates chosen are the closing Monday price and rate. If, however, Monday is a non-business day (e.g., holiday) it is relocated to the next available business day.

inflation to German levels ... [however] by mid-1987 ... the Irish-German [interest rate] differential almost disappeared".[5] Therefore, up to mid-1987 there is little evidence of integration of Ireland with Germany.[6] This coincides with the 1987 stock market crash and thus, for stock markets, provides a convenient division of the sample. The time sets are given as

(i) January 17, 1983, through October 12, 1987:
the period before the 1987 stock market crash.
(ii) October 19, 1987, through December 7, 1987:
the period of and just proceeding the stock market crash.
(iii) December 14, 1988, through February 15, 1993:
the period after the stock market crash. A period of greater financial and economic integration of Ireland with Germany.

The characteristics of stock market returns provide a general comparison of the three stock markets. This gives an insight into the relationship between stock markets.

The standard deviation of the returns for the three stock markets between 17/1/83 and 15/2/93 was large, being consistently over 2 per cent per week. This was also the case for the two subperiods before and after the crash. The standard deviation for the crash period itself, 19/10/87 through to 7/12/87, was over 8 per cent for the three markets.

For the three markets, stocks yielded an average weekly return of about 0.3 per cent (over 15 per cent per annum) for both Ireland and Germany and about 0.15 per cent (under 8 per cent per annum) for the United Kingdom. The stock market yielded a substantially greater average return for the subperiod before the crash than after the crash, with no significant change in the standard deviation of returns. Over five times greater for the Irish stock market, three times for the UK and two times for Germany. There has been a sizable adjustment and revision downwards in expected returns after the crash for all markets.

For the full sample, the three stock market returns exhibit a significant negative skewness. None of the distributions exhibited significant skewness for the period before the crash. However, for the period after the crash both German and UK returns were significantly negative skewed. A similar

5. A number of studies have explored possible reasons for the gradual convergence of Ireland's interest rates on Germany's (for example, Giavazzi and Giovannini, 1988, 1989; and Kremers, 1990).

6. The Central Bank of Ireland also referred to the change in policy: "Since 1987 ... financial markets in Ireland have become more closely integrated with continental markets. ... [D]evelopments in Irish financial markets — particularly movements in interest rates - strongly mirror developments in our narrow band partners ..." (*Central Bank Quarterly Bulletin*, Winter 1992, p. 45).

pattern to that of skewness also holds for kurtosis (or curvature). For subperiods when market returns are significantly negatively skewed they also tend to exhibit positive kurtosis.

In summary, the three stock markets exhibit a similar pattern of returns for the full sample period. Irish stocks yielded a return approximately equal to Germany but substantially greater than the United Kingdom. The distribution of returns are both negatively skewed and leptokurtic. It is evident that the crash plays an important role in skewing the distribution. This is especially the case for Ireland and to a lesser degree the UK and Germany.

The characteristics of stock market returns as described above provide a general comparison of the three stock markets. However, inference on the integration of stock markets is restricted to examining whether distributional features are similar. This measure is not an adequate test of stock market integration. The recent advancements in econometric time series methods, as outlined in the next section, provides the methodology necessary to test for stock market integration.

IV METHODOLOGY

A simple test of the integration of two stock markets is to consider the correlation coefficient between the returns of the market portfolio for the two countries. By comparing successive subperiods, one can determine whether the two stock markets have become increasingly integrated. A drawback of this test is that it is a static test measuring short-run stock market integration.

A long-run relationship between two stock market indices, j and k, can be represented by

$$\mathrm{Ln}\left(P_t^j\right) = a_0 + a_1 \mathrm{Ln}\left(P_t^k\right) + e_t \qquad (4)$$

where stock market integration in the long-run implies a linear relationship between the natural logarithms of the portfolio price indices, P^j and P^k. This is a test of the cointegration of two variable series. If $\mathrm{Ln}(P^j)$ and $\mathrm{Ln}(P^k)$ are cointegrated, the error term e_t in Equation (4) is stationary and there exists a long-run equilibrium[7] relationship between the two series.

If, as is typical for financial time series, $\mathrm{Ln}(P^j)$ and $\mathrm{Ln}(P^k)$ are both non-stationary and their first differences R^j and R^k are stationary, they are

7. With the cointegration literature all that is meant by equilibrium is that it is an *observed* relationship which has, on average, been maintained by a set of variables for a long period (Engle and Granger, 1987, 1991).

integrated of the order one, I(1).[8] When each price index is I(1) and there is a linear combination of the $Ln(P^j)$ and $Ln(P^k)$ that is stationary,[9] the two sets of prices are said to be cointegrated and hence there exists a form of long-run stock market integration.

Also, of interest is the existence of lead-lag relationships between the stock markets. That is, whether one stock market index helps forecast another price index. Given the small size of the Irish stock exchange, such relationships are likely to be present. The Granger-causality test, expressed as a vector autoregression (VAR) in the first differences, determines if lead-lag relationships exist and in what direction. Equation (5) represents the traditional Granger regressions, when market k is said to cause (leads) market j, provided some coefficient v_i^j is not zero

$$R_t^j = q_0^j + \sum_{i=1}^{m} v_i^j R_{t-i}^k + \sum_{g=1}^{m} \lambda_g^j R_{t-g}^j + \text{error} \tag{5}$$

Similarly, j is causing k if some v_i^k is not zero

$$R_t^k = q_0^k + \sum_{i=1}^{m} v_i^k R_{t-i}^j + \sum_{g=1}^{m} \lambda_g^k R_{t-g}^k + \text{error} \tag{6}$$

If both of these events occur, there is bi-directional feedback. When only one event occurs there is uni-directional feedback. The test for causality is based on an F-statistic which is calculated by estimating the above expression in both constrained $\left(\sum v_i^j = 0 \text{ and } \sum v_i^k = 0\right)$ and unconstrained forms and is given by,

$$F^* = \frac{(SSE_c - SSE_u)/m}{SSE_u/(T-2m-1)} \sim \chi_m^2 \tag{7}$$

where

SSE_c, SSE_u = residual sum of squares of the constrained and unconstrained models, respectively.
T = total number of observations,
m = number of lags.

The F-statistic, F^*, tests for the joint significance of the coefficients of the lagged changes.

8. This result may not be typical for the Irish stock exchange, as it is small with relatively few listed stocks; the majority of which are thinly traded. Jennergen and Korsvold (1974) argue that stock prices in small markets are less likely to follow a random walk (i.e. non-stationary) and, therefore, these markets are more likely to be inefficient. Furthermore, the size and trading structure of these markets implies that information may not be readily available, making it more costly for investors to acquire information.

9. That is, in Equation (4) e_t is stationary.

In the presence of cointegration the Granger causality tests, are misspecified. The Granger regressions must be adjusted by incorporating the residuals from the cointegrating regression, Equation (4), as an additional independent variable in the Granger regression equations. The adjusted Granger regressions are given by the following equations:

$$R_t^j = b_0^j + \sum_{i=1}^{m} c_i^j R_{t-1}^k + \sum_{g=1}^{m} d_g^j R_{t-g}^j + \gamma \hat{e}_{t-1} + \text{error} \tag{8}$$

$$R_t^k = b_0^k + \sum_{i=1}^{m} c_i^k R_{t-1}^j + \sum_{g=1}^{m} d_g^k R_{t-g}^k + \varphi \hat{e}_{t-1} + \text{error} \tag{9}$$

where the error-correcting coefficients given by γ and φ.

V EMPIRICAL RESULTS

As an initial step in testing the degree of segmentation and the integration of stock markets over time is to calculate the correlation coefficients between the returns on the market portfolio for the two countries. A significant increase in the correlation coefficient implies an integration of the two stock markets.

Correlation coefficients of Irish stock market returns with those of the UK and German stock markets, for each of the subperiods are reported in Table 1. There appears to be a substantial change in the correlation between subperiods. This is especially the case with regard to the period of the stock market crash, a substantial decrease in the correlation of Ireland with Germany and a substantial increase with the United Kingdom. However, for that period the standard errors of the correlation coefficient showed a marked increase, indicating volatile movement in the correlation of stock market returns. The results indicate that during the crash the focus of the Irish stock exchange was on price movements in the UK stock exchange rather than the German exchange.

Comparing the period after and the period before (but not during) the crash, there is a significant increase in the correlation coefficient of Ireland with both the UK and Germany.[10]

10. A formal test for equality of the correlation coefficients across the subperiods is provided by Kendall and Stuart (1967, p. 984). Denoting two subperiods by subscripts 1 and 2, under the null hypothesis H0: $\rho_1 = \rho_2$, the test statistic is

$$\frac{\frac{1}{2}\left\{\text{Ln}\left[(1+r_1)/(1-r_1)\right] + \text{Ln}\left[(1-r_2)/(1+r_2)\right]\right\}}{\left[1/(T_1-3)\right] + \left[1/(T_2-3)\right]}$$

and is distributed approximately standard normal. The sample correlation coefficient is given by r and the population by ρ and T_1 and T_2 are the number of observations in each sub-period.

Table 1: *Correlation of Stock Market Returns*

Correlation of Ireland with	*(1) Full Period 17/1/83-15/2/93*	*(2) 17/1/83-12/10/87*	*(3) 19/10/87-7/12/87*	*(4) 14/12/87-15/2/93*	*(5) Test (2) = (4)*
United Kingdom	0.2172 (0.0018)	0.0026 (0.0041)	0.4561 (0.1320)	0.1975 (0.0036)	–25.9478
Germany	0.2657 (0.0018)	0.1441 (0.0040)	0.0064 (0.1667)	0.3223 (0.0033)	–61.3494

Note: Standard errors of the correction coefficients are given in parentheses.

These results suggest that, there has been a significant increase in the correlation of short-run stock market returns. A substantial higher correlation of Ireland with Germany is recorded. This implies an increased integration of the Irish stock market with both the UK and German markets.

In summary, there had been a marked increase in the correlation of Ireland with the UK during the period of the stock market crash. However, excluding the crash period, the short-run correlation of Ireland with Germany has increased over time, at a level greater than the correlation of Ireland with the United Kingdom.

In order to get more insight into the integration of the Irish market with the UK and German stock markets, cointegration techniques are applied. Such results will indicate if there exists a long-run relationship between two stock markets, and whether the relationship implies that the markets are highly correlated. The existence of a highly correlated long-run relationship between two stock markets indicates that there exist little gains from diversifying beyond one market to both markets.

The results of the unit root tests for both stock market indices and returns are presented in Table 2. In the case of the stock market indices, the null hypothesis of a unit root cannot be rejected, at all relevant significance levels. Only the German stock market index (FAZ) marginally rejects the unit root hypothesis at the 10 per cent level. In contrast, even at the 1 per cent level, none of the stock market returns accept the hypothesis of unit root. Therefore, the stock market indices are integrated of the order one, I(1), for each of the time periods studied. First differencing the stock market indices induces stationarity.

Table 3 reports the results of the application of Equation (4), the cointegrating regression, to the stock market indices. Two test statistics are computed under the null hypothesis of no cointegration. The traditional test, the augmented Dickey-Fuller (ADF) test, at no time rejects the hypothesis of no cointegration, even at the 10 per cent significance level.[11] The results

11. In each case the number of lags is 4. Adding higher order of lags did not alter the qualitative findings.

Table 2: *Unit Root Test for Stock Market Indices and Returns*

	Stock Market Index		
	Full Sample 17/1/83-15/2/93	*17/1/83-12/10/87*	*14/12/87-15/2/93*
Ireland	-2.0959	-1.0799	-3.0393
United Kingdom	-2.9226	-2.4708	-1.8791
Germany	-2.4802	-1.5386	-3.2011
	Stock Market Returns		
	Full Sample 17/1/83-15/2/93	*17/1/83-12/10/87*	*14/12/87-15/2/93*
Ireland	-9.3277	-7.1440	-5.9376
United Kingdom	-9.7959	-7.4172	-6.8256
Germany	-10.0481	-7.5260	-6.8047

Note: The critical values for Dickey-Fuller t-statistic τ, for the null hypothesis of unit root, are -3.13 at the 10 per cent significance level, -3.42 and -3.98 at the 5 per cent and 1 per cent levels, respectively.

Table 3: *Cointegration Tests for Stock Market Indices*

Cointegrating Regression $Ln(P^j = a_0 + a_1 Ln(P^k) + e_t$	*17/1/83 - 15/2/93*		*17/1/83 - 12/10/87*		*14/12/87 - 15/2/93*	
(Country j, Country k)	ADF	Z_α	ADF	Z_α	ADF	Z_α
(Ireland, United Kingdom)	-1.70	-6.670	-0.534	-1.283	-2.169	-10.179
(Ireland, Germany)	-1.585	-6.566	-2.327	-10.414	-2.617	-6.973
(United Kingdom, Ireland)	-2.618	-11.240	-1.642	-4.715	-1.831	-8.895
(Germany, Ireland)	-1.026	-0.412	-2.225	-10.113	-0.168	-1.316

Notes: The critical values for the Augmented Dickey Fuller (ADF) t-stastic ϕ for null hypothesis of no cointegration, are 2.84 at the 10 per cent level of significance, 3.17 and 3.77 at the 5 per cent and 1 per cent levels, respectively.
The critical values for the Z_α-statistic for the null hypothesis of no cointegration, are -16.65 at the 10 per cent level of significance, -20.05 and -27.86 at the 5 per cent and 1 per cent levels, respectively.

of the Z_α Phillips-Ouliaris test also indicate the absence of cointegration between stock market indices.[12]

This implies that there exists no long-run relationship either between the Irish and UK stock markets or the Irish and German stock markets. Therefore the hypothesis that there exist no long term gains for Irish investors diversifying into either the UK or German stock markets is rejected. However, from Table 1, the short term gains from diversifying into either the UK or German stock market have marginally decreased over time

12. A lag window of 2 was chosen.

since returns for the stock markets have become more correlated.

In order to get more insights about the relationships of the Irish to the UK (and to the German) stock markets, the Granger causality regressions, Equations (5) and (6), are reported. These test for the presence and direction of lead-lag relationship between stock markets.

Table 4 tabulates the main findings of the Granger causality tests. The F^*-statistic tests the null hypothesis of no Granger-causal relationship between the Irish and UK, and between the Irish and German, stock markets. For the pre-crash period, the null hypothesis of no causality cannot be rejected. This indicates the absence of significant lead-lag or feedback relationships.

For the post-crash period, there is a significant increase in the F^*-statistic.[13] The results indicate the presence of Granger causality running from the German and UK markets to the Irish stock market, but not in the opposite direction. That is, there exists uni-directional causality to the Irish stock market: the United Kingdom leads Ireland and Germany leads Ireland. However, in the UK case the uni-directional causality is only significant at the 20 per cent level. Also note that the period of increased economic and financial integration of the Irish and German economies, the post-crash period, coincides with the dramatic increase in the calculated F^* between the two periods with the German stock market.

Table 4: *Granger Causality Tests*

Null Hypothesis: i does not Granger-cause j (i → j)	*17/1/83-15/2/93 F(4,513)*	*17/1/83-12/10/87 F(4,234)*	*14/12/87-15/2/93 F(4,262)*
United Kingdom → Ireland	6.8454*	0.5732	6.9449*
Ireland → United Kingdom	2.5245	0.9948	1.4838
Germany → Ireland	26.8711**	3.1474	12.4450**
Ireland → Germany	1.3508	1.9069	0.3488

Notes: *Significant at the 20 per cent level.
**Significant at the 1 per cent level.

The F^*-statistic for the full sample period is also reported in Table 4. As in the case of the post-crash period, there exists uni-directional causality to the Irish stock market. This provides further evidence that the Irish stock market is inefficient.[14]

Furthermore, by including the current values for the stock market returns

13. To ensure white noise residuals, m = 4 for each case. Adding higher lags did not alter the qualitative findings.

14. Also, see McKillop and Hutchinson (1987).

in the Granger causality regressions as an extra explanatory variable, that is, R^k in Equation (5), and R^j in Equation (6) contemporaneous causality can be tested. This allows for the fact that R^j and R^k may affect each other contemporaneously. Their estimated coefficients, reported in Table 5, are significant for all stock market Granger-causal relationships for the post-crash period and over the full sample. However, for the pre-crash period no significant contemporaneous causality between the Irish and UK markets is observed and is insignificant at the 1 per cent level with the German market. This result is similar to that of the earlier causality tests; causality is absence pre-crash period but present post-crash period.

Table 5: *Contemporaneous Causality Tests*

Null Hypothesis: i does not Granger-cause j	*17/1/83-15/2/93*	*17/1/83-12/10/87*	*14/12/87-15/2/93*
United Kingdom → Ireland	0.1620	–0.0105	0.1568
	(0.0384)	(0.0615)	(0.0489)
	[4.2173]	[–0.1709]	[3.2034]
Ireland → United Kingdom	0.2072	–0.0119	0.2413
	(0.0491)	(0.0697)	(0.0753)
	[4.2173]	[–0.1709]	[3.2034]
Germany → Ireland	0.2707	0.1813	0.3197
	(0.0419)	(0.0754)	(0.0574)
	[6.4613]	[2.4025]	[5.5692]
Ireland → Germany	0.2785	0.1336	0.3322
	(0.0431)	(0.0555)	(0.0597)
	[6.4613]	[2.4025]	[5.5692]

Notes: The 5 per cent significance level is given by 1.96, 10 per cent by 1.645, and 1 per cent by 2.576. Standard errors are given in parentheses, and t-statistics are given in square brackets.

A substantial increase in contemporaneous causality between the Irish stock market and both the UK and the German markets for the two sub-periods is detected. This result reinforces the conclusion drawn from Table 1. The increasing importance of the German stock market to the Irish stock market is indicated by a larger contemporaneous causality coefficient than that of the UK, increasing from 0.2707 to 0.3197 (and from 0.2785 to 0.3322). From the results of the short-run correlation coefficients and the contemporaneous causality results, there is a low level of integration of the Irish stock market with the German market. This level is, however, higher than the integration with the United Kingdom. Therefore, for Irish investors there exists gains from diversifying their portfolio across countries; the UK providing a larger gain than Germany.

In summary, the contemporaneous Granger causality test addresses two issues; the efficiency of the Irish stock exchange and diversification possibilities. The correlation coefficient indicates the level of stock market integration and therefore the possibility of gains from diversification. A similar measure is the contemporaneous coefficient. The larger the value on the coefficient the lower the possibility of gains from diversification. Whereas, significant lead-lag relationships suggests that the market is inefficient.

Finally, the importance of the stock market crash has been highlighted in a number of recent international studies. A comprehensive analysis is provided by Roll (1988). However, little attention has been given to the effect of the crash on the integration of the Irish stock market with other stock markets.

Using *daily* data, the 1987 stock market crash period, October 19, 1987, through December 11, 1987, is tested for causal relationships. Table 6 summarises the results. These results indicate that there exists two cointegrating relationships; the Irish and the UK stock market indices and the Irish and the German stock market indices.[15] The Granger causality tests indicate no lead-lag relationship. However, the contemporaneous causality coefficients show that feedback occurs immediately without a lag. That is, the effect of

Table 6: *Cointegration and Granger Causality Tests for the Period of the Stock Market Crash, 19/10/87 to 11/12/87*

Cointegrating Regression $Ln(P^j) = a_0 + a_1 Ln(P^k) + e_t$ *(Country j, Country k)*	*ADF*	Z_a	*Granger-Causality Test F(2,35)* $k \rightarrow j$	*Contemporaneous Coefficient*	*Error-correcting Coefficient* γ *and* φ
(Ireland, United Kingdom)	–1.832	–13.051	1.665	0.8024 (0.1153) [6.9585]	
(Ireland, Germany)	–2.742	–28.279	0.158	1.0475 (0.1389) [7.5424]	0.0253 (0.3466) [0.0073]
(United Kingdom, Ireland)	–3.569	–23.490	1.510	0.6592 (0.0786) [8.3867]	–0.4686 (0.2066) [–2.2681]
(Germany, Ireland)	–2.980	–28.037	1.017	0.5712 (0.0815) [7.0045]	–1.0409 (0.3688) [–2.8224]

Note: As Tables 2, 3 and 4. The order of lagged of m = 2, was chosen to ensure white noise residuals. Standard errors in parentheses, and t-statistics are given in square brackets.

15. Note that the FTSE-100 is cointegrated with the ISEQ, but the reverse, the ISEQ cointegrated with the FTSE-100 cannot be accepted.

the crash had a simultaneous effect on the three markets, with no significant lead-lag effects.

The results here are consistent with similar international studies. More recently, Malliaris and Urrutia (1992) considered six stock market indices and detects important feedback relationships and unidirectional causality for the October 1987 crash. They suggest that the crash was an international crises that occurred simultaneously in all the stock markets.

VI SUMMARY AND CONCLUSION

The interdependencies between the Irish and UK stock markets, using the ISEQ and the FTSE-100 stock market indices were examined. Arising from the greater economic and financial integration between Ireland and Germany, the degree of integration of the ISEQ and the FAZ stock market indices is also assessed.

Although the Irish and the UK stock exchanges are connected by a common system of standards and regulation, there does not appear to exist a long-run relationship between the two stock markets. The application of cointegrating techniques also indicates a similar result for the integration of the Irish and German stock markets. However, there has been a significant increase in the correlation of short-run stock market returns as a result of a greater financial and economic integration with Germany.

Full integration implies simultaneous adjustment to new information coming into markets, thereby eliminating any opportunities for abnormal profits associated with lagged information processing. However, from the interdependencies among these markets and the lead-lag structure as identified, an investor, for instance in Ireland could anticipate stock price changes in the Irish market by observing Germany's stock market and perhaps derive abnormal returns.[16] The presence of a lead-lag relationship suggests that the market is inefficient.

There exist potential gains to an Irish investor from diversifying portfolios across countries. The absence of a long-run relationship is likely to result in the benefits accruing both in the short-run and the long-run. The relaxation of exchange controls that economic and monetary union brings should allow Irish investors to invest in an efficient portfolio by moving their funds into other stock markets. This is likely to have serious consequences for the development of the Irish stock market.

Using Granger causality tests, lead-lag relationships between the ISEQ index and the FTSE-100, and the FAZ, indices were analysed. Practically no

16. This claim should be considered in the light of wide bid-ask spreads and thin trading on the Irish stock market.

lead-lag relationships were found in the pre-crash subperiod. However after the crash, a period of greater integration of the Irish economy with that of Germany, evidence of unidirectional causality is found between the Irish and German markets; the German stock market leading the Irish market. Also, the UK, whilst less significant, leads the Irish market. These relationships indicate that the Irish stock market is inefficient. Furthermore, there is an increase in contemporaneous causality during the post-crash subperiod. The increase is not sufficient to accept the hypothesis of no gains for Irish investors diversifying in to either the UK or German stock markets. The results indicate that not only is the Irish stock market inefficient, it is also segmented with both the UK and German markets. Thus the cost of raising capital for a project on the Irish stock market is likely to be greater than for a similar project in a market that is efficient.

During the period of the stock market crash there had been a marked increase in the correlation of the stock market returns of Ireland and the United Kingdom. The results from the contemporaneous causality tests confirm and clarify international studies which found that the crash started more or less simultaneously for the three stock markets.

In summary, the results have important implications for the efficiency of the Irish stock market. The causality tests indicate that the Irish market is inefficient. Furthermore, not only do there appear to be short-run gains from diversifying internationally but gains persist into the long-run.

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